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A New 40 Meter Radiotelescope at Yebes (Spain) for Geodetic VLBI Studies

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Abstract

The construction of a new 40-m parabolic radiotelescope at Yebes, near Madrid (Spain), is being finalized. The instrument, built by the Spanish Instituto Geográfico Nacional (Ministerio de Fomento) will soon operate at frequencies between 2 and 115 GHz, and will become a key partner for both the astronomical (in European and global projects) and the geodetic VLBI communities (through IVS), with an estimated participation in observations of 50 days/year for the latter.

During the last decade, IGN has collaborated in the EUROPE and CORE campaigns with the 14-m radiotelescope. The staff is acquainted with the concepts, observing procedures and instrumentation involved. New infrastructures are being constructed in Yebes, such as a high speed fiber optic link to GEANT, and a new building to hold a gravimeter system, in order to enable the station to become a geodetic fundamental station soon. Scientific projects in Geodesy and Astrometry are also being conducted by IGN scientists.

1. Introduction

The Observatorio Astronómico Nacional (OAN) of Spain, which is a department of the Instituto Geográfico Nacional (IGN, Ministerio de Fomento), operates a 14 meter radiotelescope at Yebes (Guadalajara, Spain). This facility has been a network station of the IVS until 2003, and has participated regularly in the geodetic VLBI campaigns to study the tectonic plate motions in Europe, Earth rotation, and pole motion. The main contribution of OAN to IVS is the realization of geodetic VLBI observations. Table 1 shows the observing campaigns in which Yebes (14-m) has participated in the period 1995-2003.

The construction of a new 40 meter radiotelescope is nearly completed in Yebes (see Fig. 1). A new S/X receiver will be installed in 2006, in order to resume geodetic VLBI observations. The VLBI equipment has been constantly upgraded (including Mark 5A) and is fully operational.

Table 1. Number of geodetic VLBI sessions Yebes has observed (1995-2003).

Experiment type	CORE-B	EUROPE	IVS-T2
Number of Sessions	13	21	5

Figure 1. The new 40-m radiotelescope of OAN at Yebes, for geodetic and astronomical VLBI.

2. Description of the 40 Meter Radiotelescope

The 40-m radiotelescope is of turning-head type on an azimuth-elevation mount. The optical configuration is a Nasmyth-Cassegrain system: parabolic reflector, hyperbolic subreflector, and a 45° flat mirror to reflect the beam laterally. The Nasmyth focus is at 11 meters from the vertex of the paraboloid, therefore the instrument has a large receiver cabin for optimal frequency flexibility.

Moreover, the telescope subreflector can be placed in two positions: one for primary focus operation (exposing the primary focus receiver horn through a hole in the subreflector center), the other for the Nasmyth-Cassegrain focus. In this second case, the subreflector can be moved with high precision (30 μm) on six axes to correct the gravity deformation of the telescope backstructure (see Fig. 2). The telescope is designed following the homology principle (when deformations change the paraboloid, the focus change is corrected for by moving the subreflector). The surface panel precision is better than 60 μm, with a total surface rms of 150 μm. This allows a maximum observing frequency of 120 GHz, with an aperture efficiency of 50%. The minimum frequency of operation is set by the size of the beams inside the receiver cabin, and is around 2 GHz. Pointing is better than $5''$ (winds below 10 m/s). The telescope is designed to survive winds up to 50 m/s.

The final design and control of the works has been made by the German company MAN Tech-

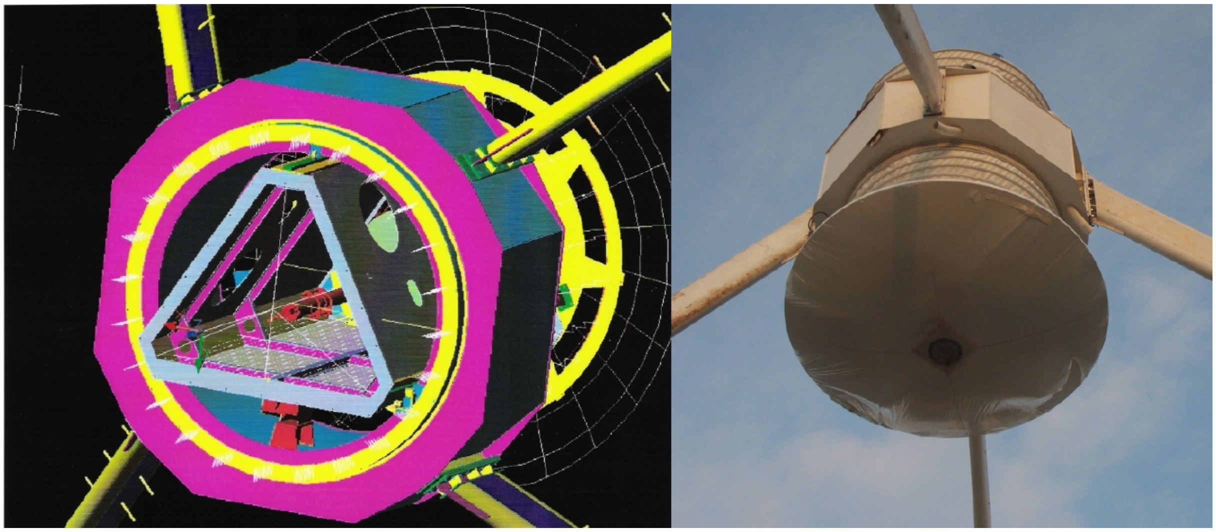

Figure 2. Left: sketch of the subreflector (M2) support structure. Right: actual subreflector cabin.

Table 2. RMS error budget of the 40-m radiotelescope surface.

	RMS
Panels	65 μm
Panels deformation	25 μm
Deformation steel structure (15 m/s wind)	95 μm
Mechanical alignment	80 μm
Total	150 μm

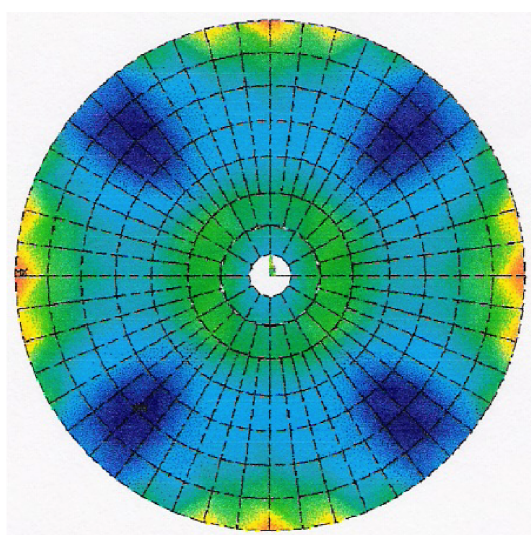

Figure 3. Expected gravity deformations of the 40 meter radiotelescope.

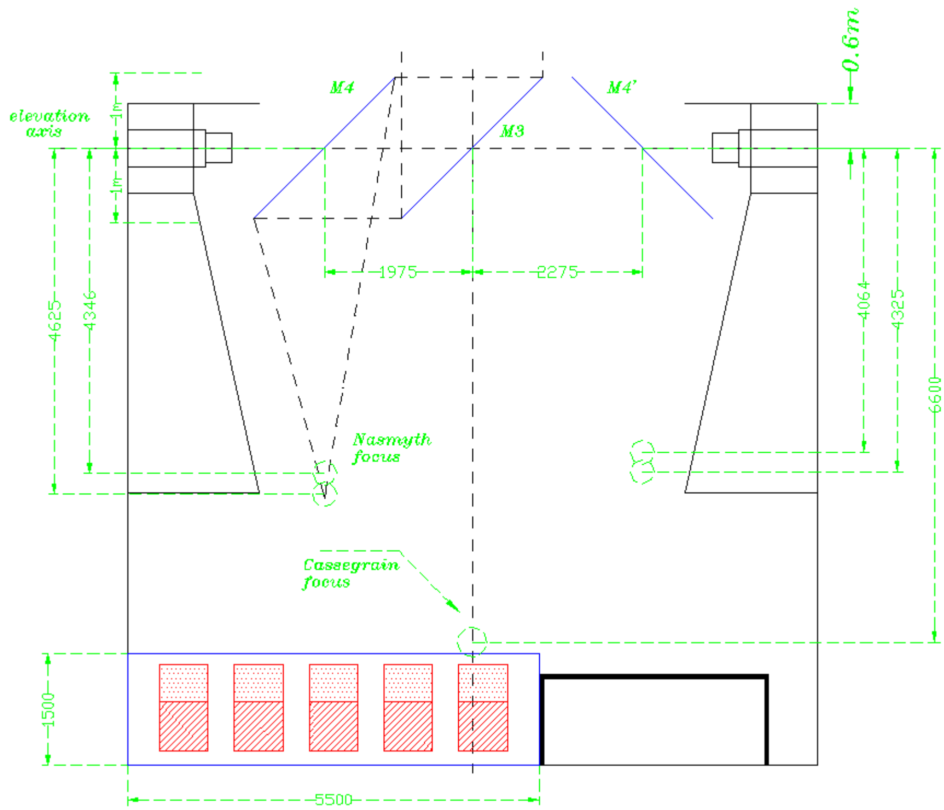

Figure 4. Sketch of the 40-m radiotelescope receiver cabin.

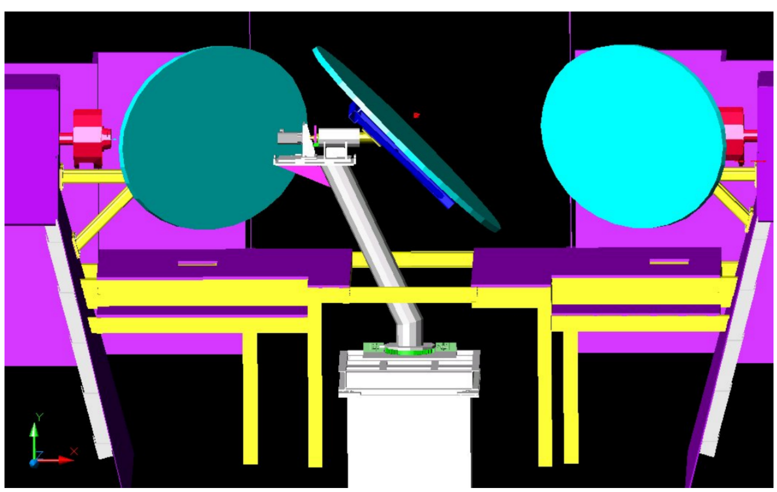

Figure 5. Nasmyth mirror (center) and two M4/M4' mirrors.

Figure 6. M5 mirror support of the low frequency branch M4'.

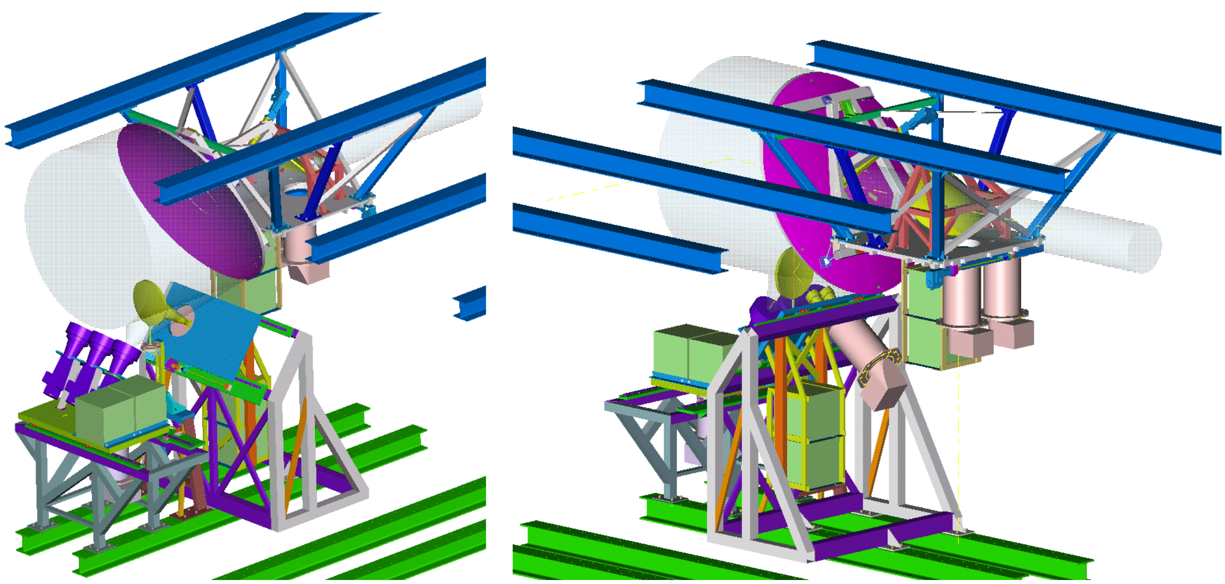

Figure 7. Configuration of the S/C/Ch (purple horns in the left image) and X/Ku (small yellow horns in the right image) receivers on the M4' branch.

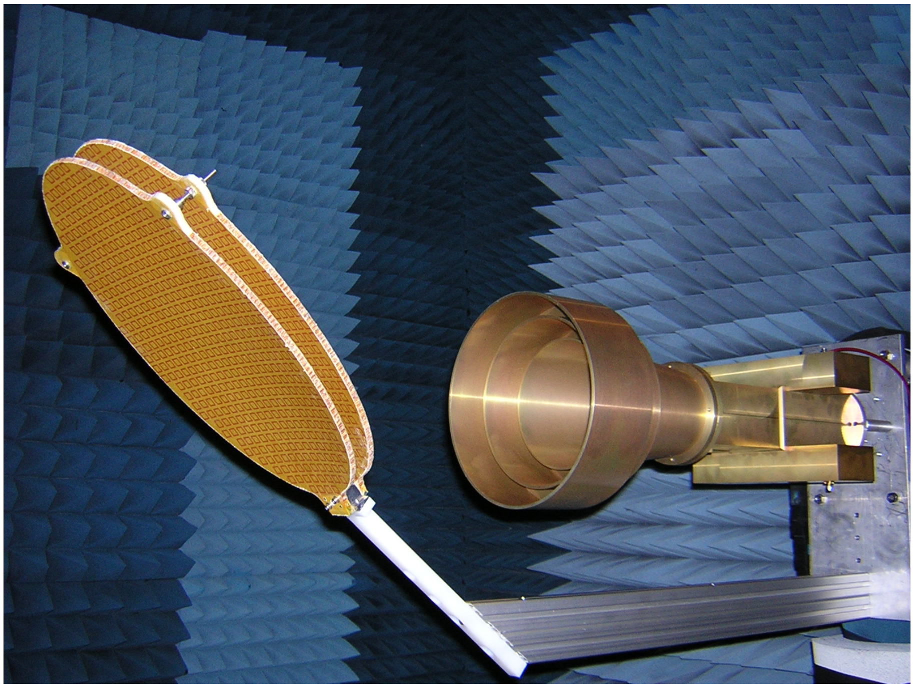

Figure 8. S-band horn with polarizer and dychroic mirror.

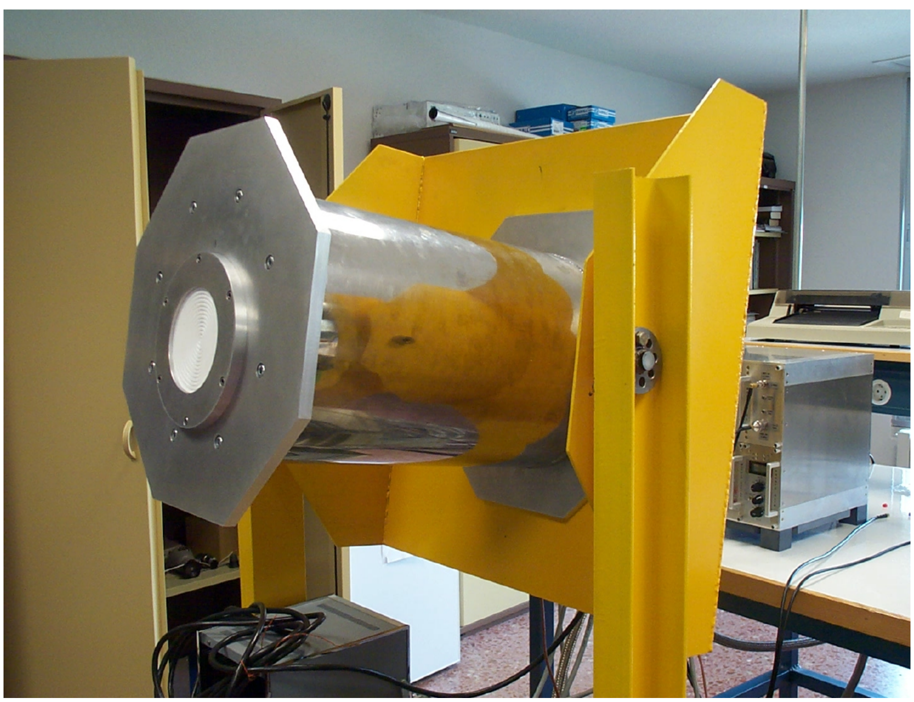

Figure 9. Cryostat of the 22 GHz receiver.

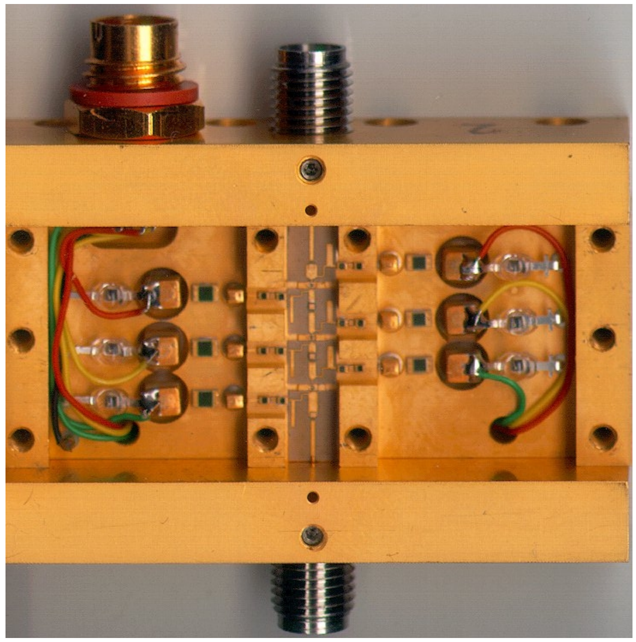

Figure 10. Details of a HEMT amplifier of the 22 GHz receiver, designed and built at OAN-Yebes.

nologie AG (now MT Aerospace AG). The concrete tower was built in 1999 by ACS (Spain), and the rest of the instrument by Schwartz-Hautmont Construcciones Metálicas (Tarragona, Spain). The elevation rotating structure weighs 500 tons, where 200 tons are for the trusswork and 100 tons are for the 420 panels. The backstructure is covered by a protective cladding, which is ventilated inside to avoid asymmetric warming of the structure.

The receiver cabin is very large: 8 × 9 × 3.5 meters. It is divided into two independent branches, selected by moving the Nasmyth mirror (M3) towards two other mirrors, called M4 and M4'. This defines two different foci, located at about 4.5 meters from the M4 mirrors. The M4 branch will hold the high frequency receivers (above 22 GHz), while the M4' branch will hold the low frequency ones. Up to seven frequency bands can be supported on the M4' branch: S, X, C, Ku, 22 GHz and 30 GHz. This configuration allows simultaneous observations with at least two receivers. Note that the 30 GHz receiver may be installed in any of the two branches, allowing simultaneous observations with the current geodetic VLBI S/X receivers.

All receivers are designed for double circular polarization (LCP and RCP), and will be operated by remote control. The first to be installed will be those of the 20.75 – 24.45 GHz band, the new S/X (early in 2007) and C (5–6 GHz) bands, followed later by the millimeter receivers (76–116 GHz, and 40–50 GHz). Other receivers (3.3 GHz and 30 GHz) are under study. An additional receiver on the Ku band (12 GHz), uncooled, will be installed on the primary focus cabin to perform holographic measurements of the main reflector, in order to adjust the paraboloid surface with high precision.

The telescope will move in the range of -90° to $+430^{\circ}$ in azimuth and 0° to 90° in elevation, at a maximum slew speed of 3°/s in azimuth and 1°/s in elevation. The minimum slew velocity is 0.0001°/s, for a pointing accuracy better than $5''$ with winds up to 10 m/s (normal operation).

3. Other Instrumentation at OAN–Yebes

3.1. The 14-m Radiotelescope

The Observatorio Astronómico Nacional (OAN) operates a 14 meter radiotelescope at Yebes (Guadalajara, Spain). This facility has been a network station of the IVS until 2003, and has participated regularly in the geodetic VLBI campaigns to study the tectonic plate motions in Europe, Earth rotation, and pole motion. This instrument is however not operational nowadays, therefore VLBI observations will be resumed after the completion of the new 40 meter radiotelescope described above.

3.2. GPS

The GPS station at Yebes (Fig. 11), established in 1999 and run by IGN, is the reference point of the Spanish fiducial network since 2002. In 2004, it became an IGS station with code 'YEBE'. It uses the station H-maser as reference.

In 2001, a new analysis center for EUREF was set up by IGN in Madrid ('IGE'). It processes 30 stations from Spain, Portugal, Morocco, France, and UK, among others. It is one of 15 EUREF LACs (local analysis centers).

3.3. Gravimetry

Measurements of absolute gravity at the 14-m telescope building have been performed. A project of constructing a building is being finalized, which will allow the installation of permanent equipment for constant gravity monitoring (see Fig. 12).

4. Research

The OAN group performs high precision astrophysical VLBI studies of maser emission towards late-type stars, which will not be discussed here. However we point out that we have modified the Astronomical Image Processing System (*AIPS*) to allow the processing of full polarization data on antennas with Nasmyth optics. Similar developments will be needed if full polarization is to be used in geodetic VLBI, following the VLBI2010 project.

The OAN group is working on a new method, *Source/Frequency phase referencing*, to measure frequency-dependent position shifts of source cores with high accuracy. The first successful application to measure the core shift of the quasar 1038+528 A at S and X-bands has been reported, and the results have been validated by comparison with those from standard phase referencing techniques (Rioja et al., 2005). The method is an extension of the technique developed and demonstrated by Middelberg et al. (2005), which uses fast frequency switching observations and relies on the transfer of calibration from the lower to the higher frequency. Our new proposed method endows it with astrometric applications by adding a strategy to calibrate the ionospheric contribution. We forsee it holds a big potential at high frequencies, in particular when applied to observations of molecular line emission. In geodesy unaccounted source core shifts introduce errors in the estimated ionospheric-free observables, and hence in the astrometric/geodetic products from the analysis.

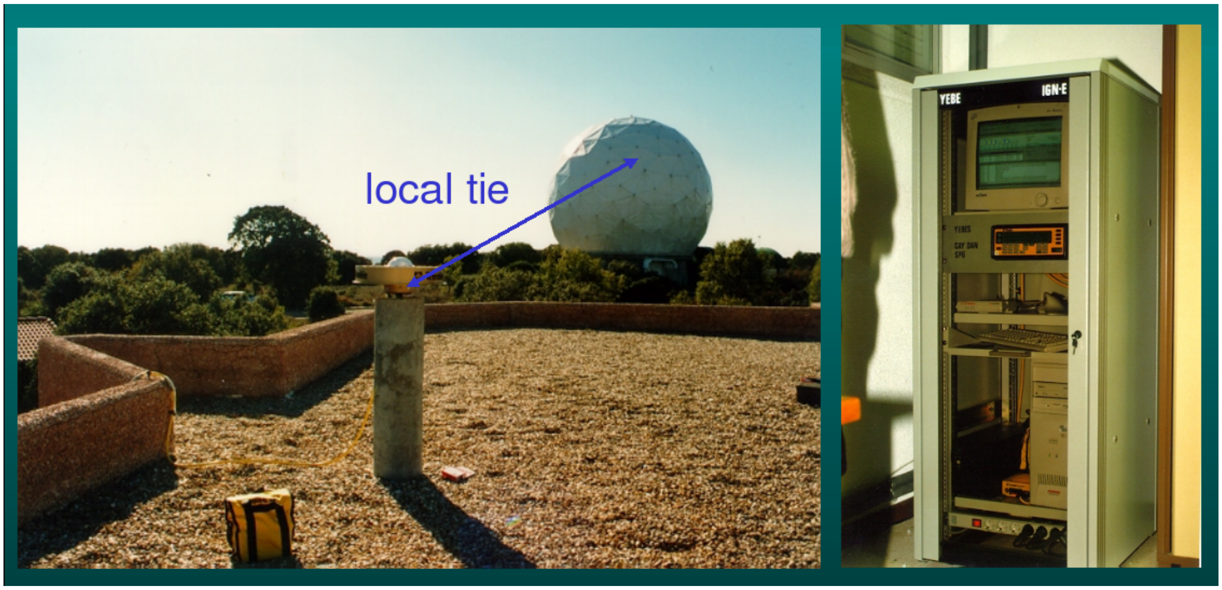

Figure 11. The IGS station “YEBE”.

Figure 12. Artistic impression of the gravimeter building in Yebes (center), with sketch of the possible location (right) of the gravimeters (left).

5. Future Plans

We expect first-light on the new 40 meter radiotelescope at Yebes in 2006, after the construction and commissioning are finished. The telescope is expected to be operational at S/X bands by the end of 2006 or early 2007. Other frequencies of operation will be 4-7 GHz, 10-15 GHz, 21-24 GHz (first light receiver), 30-32 GHz, 40-50 GHz, and 72-116 GHz. Connection of this telescope to GEANT (1 Gbps fiber optics link) is progressing within the frame of the EXPReS EU project. The measurement of the 40-m phase-center and local-tie to the 14-m telescope and the GPS antenna will also be performed in 2006.

Collocation of geodetic techniques (40-m VLBI radiotelescope, GPS receiver in IGS station, and gravimeters) will allow Yebes to become a Geodetic Fundamental Station in the coming years.

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